BROWN UNIVERSITY Providence, Rhode Island 02912
Department of Geological Sciences
401 863-2526, 2417

To: Dr. Joseph Bredekamp
Applied Information Systems Research
Heliophysics Division
Science Mission Directorate
NASA Headquarters, Code SE
300 E Street SW
Washington, DC 20546-0001

Cc: Nand Lal, NASA Technical Officer
Randal L. Barnett, NASA
Nancy Fjeldheim, Department of Geological Sciences, Brown University
Rae Ann Lannon, Office of Sponsored Projects, Brown University

From: James W. Head, III
Dept. of Geological Sciences
Brown University
Providence, RI 02912

Date: August 28, 2009

Subject:
Contract No. NNX08AC63G
Advanced Visualization in Solar System Exploration and Research (ADVISER): Optimizing Science Return from the Moon and Mars

Progress Report, Years 1-2: October 30, 2007 to October 29, 2009
Principal Investigator: James W. Head, III

This project is designed to: 1) advance space science knowledge, exploration capabilities, and teaching and outreach, and 2) research advanced visualization tools for space science and education, through ADVISER (Advanced Visualization in Solar System Exploration and Research), a problem solving environment (PSE) for planetary geosciences that integrates and extends the state-of-the-art in hardware and software technologies.

Our approach is to put geoscientists on or near planetary surfaces and provide them with virtual, extended versions of traditional field tools to solve significant scientific problems, using four basic features: 1) Geoscientist on or near the surface, 2) Importation and visualization of multiple, integrated data sets, 3) field kit development, and 4) ancillary virtual field instrument development.

Over the last two years we have completed or begun the following:

1. Incorporation of the IVR facility for an Engineering course on mission design (continuing) and a Synthetic Biology course.
2. Integration with navigation system: how to plan for field work and establish traverse planning highlights with ArcGIS in order to optimize the planned input to the IVR facility.
3. Established ADVISER capabilities in our Geoscience lab and are measuring and comparing ADVISER tasks done in a spectrum of environments (i.e., Cave (CVV), 3x3 tiled powerwall (CCV), "practical powerwall" through stereo-capable commercial-off-the-shelf HDTV's (Geo and CS), and at a conventional desktop (Geo)).
4. Continue debriefing by user systems: Graduate students have discussed and described their experiences with students and faculty with all IVR facility personnel in attendance; more detailed reports are underway. Undergraduate students have provided general feedback and others are doing hands-on work to help explore optimal user interface ideas (e.g., hand-held PDA device controls and applying the latest 'video-game-like' rapid response controls). A number of demos to visitors, including members of the education and industrial communities, and participants at a meeting of the American Society of Photogrammetry and Remote Sensing, are also providing good feedback.
5. Tools for Analysis of large images and large stereo pairs. a) We developed a viewer software for panning, zooming, and interactively correcting contrast/brightness of large (up 40k x 20k) camera images from satellites. b) We developed GeoViewer, an improved version of the single-image viewer that supports viewing of hundreds of very large stereo pair images (up to 40k x 20k). c) We developed and tested algorithms for extracting quantitative measures from stereo pairs (e.g., to measure slope). And d) we implemented a computer-vision based algorithm for automatically converting large stereo pairs to DEMs and did an error analysis of its performance.
6. We designed, implemented, and evaluated five user interaction techniques for exploring large terrains. This work was presented in a poster at the ACM Symposium on Interactive 3D Graphics and Games.
7. We brought a Tablet PC (with OneNote and other pen-enabled software) and a Livescribe Pulse 2GB Smartpen to Antarctica for multiple weeks to evaluate their effectiveness as an electronic field notebook and documented the lessons learned from that investigation.

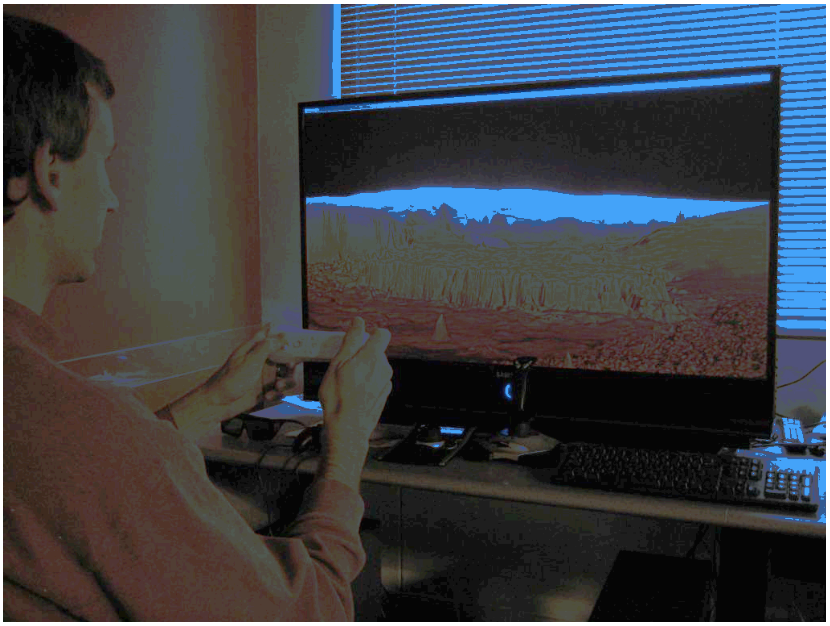

Figure 1: A user navigates using a Nintendo Wii-mote (one of multiple input devices we have investigated) across the north pole of Mars. Imagery is being displayed on a 61-inch "practical powerwall" HDTV stereo-capable display that is easily used in a laboratory and approximates the experience of a fully-immersive Cave virtual reality display.

8. Our research in the following areas resulted in a number of publications and presentations as follows:

a. Analysis of ancient regional glaciation on Mars:

- Dickson, J. L., J. W. Head and D. R. Marchant, Late Amazonian glaciation at the dichotomy boundary on Mars: Evidence for glacial thickness maxima and multiple glacial phases, *Geology* 36:5, 411-414, 2008;
- Dickson, J. L., C. I. Fassett, and J. W. Head, Amazonian-Aged Valley Networks in a Climatic Microenvironment on Mars: Melting of Ice Deposits on the Interior of Lyot Crater, *Geophysical Research Letters* 36, L08201, DOI:10.1029/2009GL037472, 2009;
- Levy, J. S., J. W. Head and D. R. Marchant, Concentric crater fill in Utopia Planitia: History and interaction between glacial "brain terrain" and periglacial mantle processes, *Icarus,* doi:10.1016/j.icarus.2009.02.018, 2009.)

b. Analysis of tropical mountain glaciers:
Kadish, S., J. W. Head, R. Parsons and D. R. Marchant, The Ascraeus Mons fan-shaped deposit: Volcano-ice interactions and the climatic implications of cold-based tropical mountain glaciation, *Icarus* 197:1, 84-109, 2008.

c. Analysis of valley networks on Mars:
Fassett, C. I. and J. W. Head, The timing of martian valley network activity: constraints from buffered crater counting, *Icarus* 195:1, 61-89, 2008.

d. Analysis of lakes on ancient Mars:
Fassett, C. I. and J. W. Head, Valley-fed, open basin lakes on Mars: Distribution and implications for Noachian surface and subsurface hydrology, *Icarus* 198, 37-56, 2008.

e. Analysis of recent gully formation on Mars:
   Head, J. W., D. R. Marchant and M. A. Kreslavsky, Formation of Gullies on Mars: Link to Recent Climate History and Insolation Microenvironments Implicate Surface Water Flow Origin, *Proceedings of the National Academy of Sciences*105:13258-13263, doi:10.1073/pnas.0803760105, 2008.

f. Analysis of lobate debris aprons:

- Ostrach, L. R. and J. W. Head, Volumetric estimates of Amazonian lobate debris aprons (LDA) in the mid-latitudes of Mars: Support for the presence of significant water-ice, Abstract 1652, 39th Lunar and Planetary Science Conference, Houston TX, March 10-14, 2008;
- Ostrach, L. R. and J. W. Head, Ring-mold craters (RMC) in lobate debris aprons (LDA) in the Deuteronilus Mensae region of Mars: Evidence for shallow subsurface glacial ice in lobate debris aprons, Abstract 2422, 39th Lunar and Planetary Science Conference, Houston TX, March 10-14, 2008;
- Kress, A. M and J. W. Head, Ring mold-craters in lineated valley fill and lobate debris aprons on Mars: Evidence for subsurface glacial ice, *Geophys. Res. Lett.,* 35, L23206, doi:10.1029/2008GL035501, 2008;
- Morgan, G. A., J. W. Head, and D. R. Marchant. Lineated Valley Fill (LVF) and Lobate Debris Aprons (LDA) in the Deuteronilus Mensae Northern Dichotomy Boundary Region, Mars: Constraints on the Extent, Age and Episodicity of Amazonian Glacial Events, *Icarus*, doi:10.1016/j.icarus.2009.02.025, 2009.

g. Studies of Mars/Antarctic Dry Valleys analogs:
   Levy, J. S., J. W. Head, D. R. Marchant, J. L. Dickson and G. A. Morgan, Geologically recent gully-polygon relationships on Mars: Insights from the Antarctic Dry Valleys on the Roles of Permafrost, Microclimates and Water Sources for Surface Flow, *Icarus* 201, 113-126, 2009;
   Levy, J. S., J. W. Head, and D. R. Marchant, Thermal contraction crack polygons on Mars: A new synthesis from HiRISE, Phoenix, and terrestrial analog studies, *J. Geophys, Res.* 114, E01007, doi:10.1029/2008JE003273, 2009.

h. Field visualization user studies:
   Forsberg, A. S., J. Chen, and D. H. Laidlaw, Comparing 3D vector field visualization methods: A user study, Forsberg, A., Chen, J., Laidlaw, D. H., "Comparing 3D Vector Field Visualization Methods: A User Study", In Proceedings of IEEE Visualization '09, Atlantic City, NJ, 2009;
   Forsberg, A. S., Huffman, J., LaViola, J. J., Dickson, J., Fassett, C., Zeleznik, R. C., Chen, J., and Head, J. W., "A Head-to-Head Comparison of Navigation Techniques for Exploring 3D Geoscience Data Sets", Poster presented at ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games, March, 2009.

The preceding efforts follow up on earlier work:

1. Imported and visualized multiple data sets, including MOLA altimetry and HRSC digital terrain models, HiRISE and CTX ultra-high resolution images, CRISM high spatial and spectral resolution imaging spectrometer data, and wind vectors and values for different seasonal atmospheric and climate conditions.

2. Placed 50 geoscientists on the surface of Mars to address scientific problems.
3. Prototyped important aspects of the field kit (field location, strike and dip determination, instant altimetry and profiles, traverse recording and on note-taking, etc.) and provided the geoscientists with these tools in the IVR environment.
4. Prototyped ancillary field instruments (e.g., virtual photography, virtual GPS, and the PDA field notebook) and provided the geoscientists with these tools in the IVR environment.
5. Continued integrating ROAM3 rendering system into the IVR environment; built toolkit on top.
6. Provided support for non-immersive desktop and immersive display environments.
7. Integrated ArcMap to formalize the initial correlation of data sets for enhancing data preparation for importing to the immersive environment.
8. Developed tablet PC pen-based UI to traverse planning application of ADVISER.
9. A Geosciences class (Mars, Moon, and the Earth) of 72 (in 2007) and 100 (in 2008) undergraduate university students used the facility during their course to plan the choice and exploration of scientifically interesting places on Mars, with another scheduled for a visit this fall.
10. Purchased hardware to explore the four-stage spectrum (desktop – fishtank – wall - IVR) and completed initial testing.

Under development are:

1. Initial mechanisms for tele-robotic viewing within Brown.
2. Initial mechanisms for tele-robotic viewing outside of Brown at NASA and with other users.
3. Data management solutions for ‘out of core’ data sets.
4. Techniques so that large data sets have low impact on interactivity (high frame rate and low latency).
5. Continuing to develop advanced visualization and rendering techniques so that large geology data sets can be viewed in immersive VR (i.e., high frame rate, low latency, without inducing cybersickness).
6. Explore and evaluate the four-stage spectrum (desktop⇨fishtank⇨wall⇨IVR).
7. Exploring different representations of Mars in immersive environments (spherical planet-like representation vs flat representation)
8. Working to make all of our applications run on multiple platforms (UNIX, Microsoft Windows, Mac OS).
9. Investigating the vertical dimension (e.g., global climate models) and integrating it with our terrain rendering techniques.
10. Extending to additional science themes and topics.